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Exploring Multi-programming Applications in the NISQ Era

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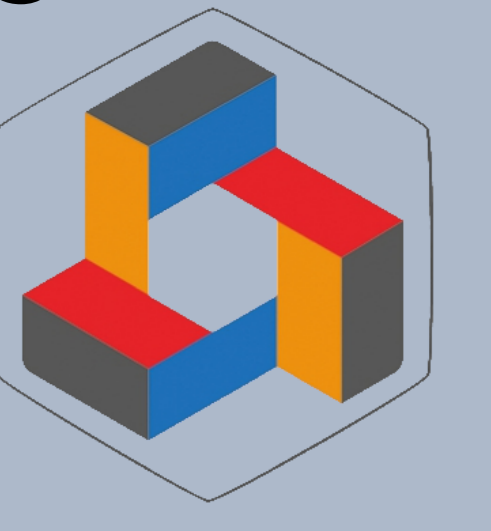
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Exploring Multi-programming Applications in the NISQ Era



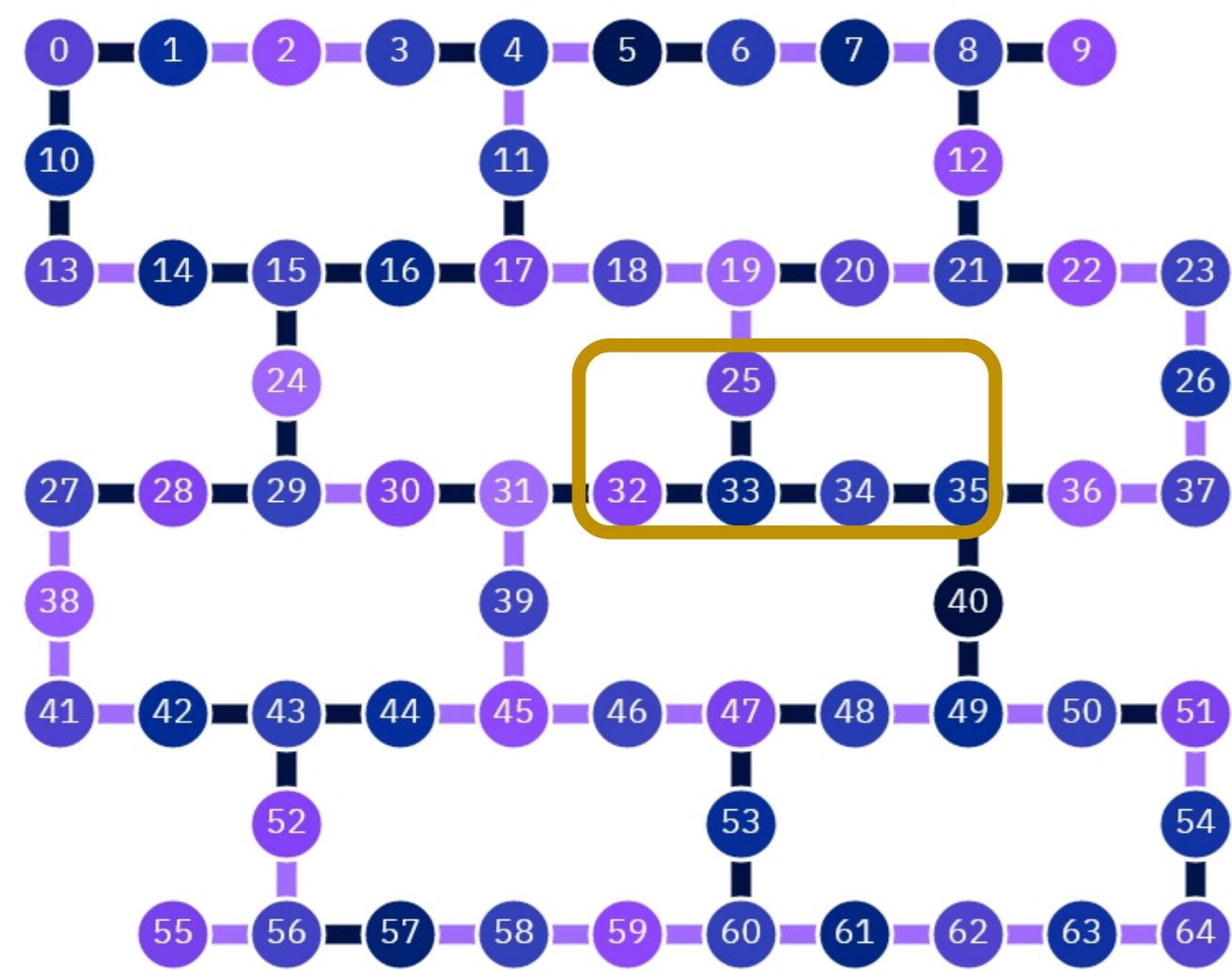
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LIRMM

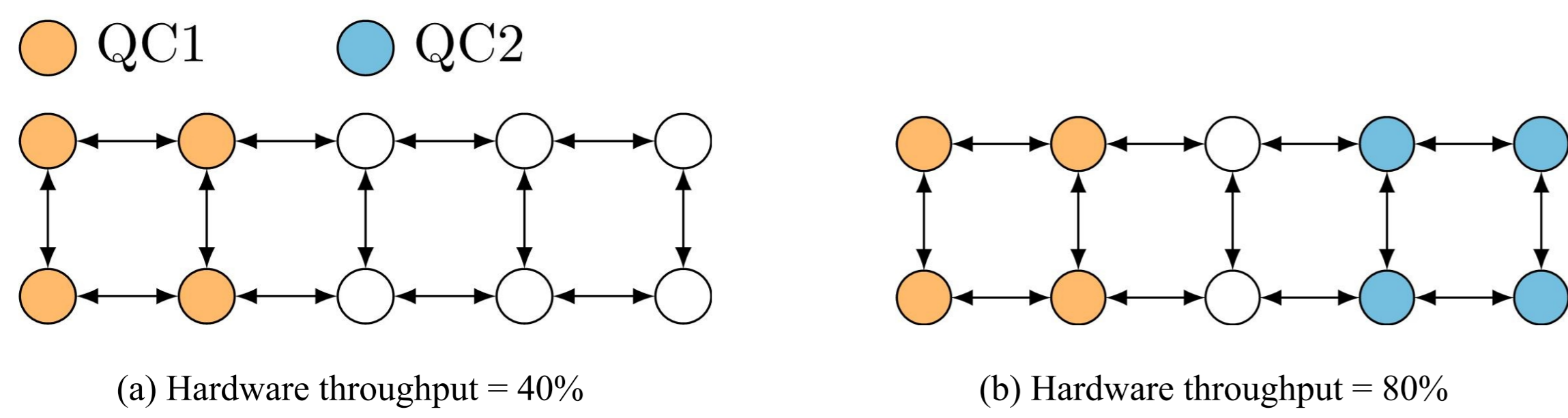


Introduction



- **Limited** hardware connectivity
- Unavoidable **error** rates
- Only **small** circuits can obtain reliable results
- **Long** waiting time
- Hardware throughput: **8%**
- Total pending jobs: **1038**

Motivation



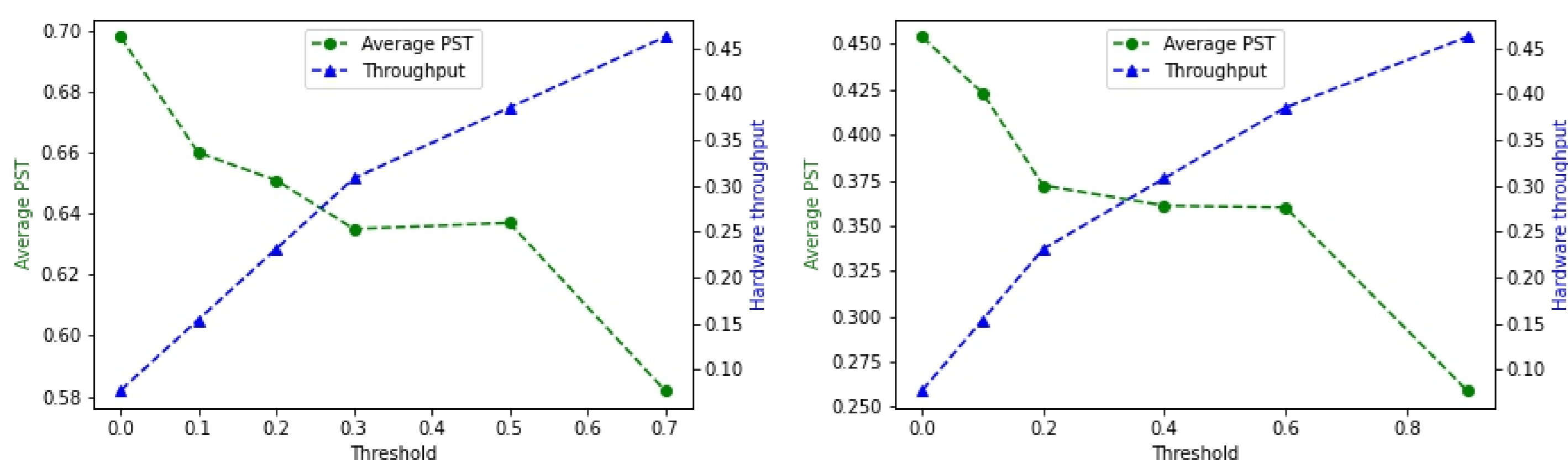
Key ideal: execute multiple circuits simultaneously to increase the hardware throughput and total runtime.

The multi-programming mechanism

Which factors should we consider to build a multi-programming technique?

- Crosstalk
- Partition qubits to reliable regions
- Qubit mapping (routing)
- Task scheduling
- Number of simultaneous circuits

Hardware throughput vs Circuit fidelity



(a) 4mod5-v1_22 result

(b) alu-v0_27 result

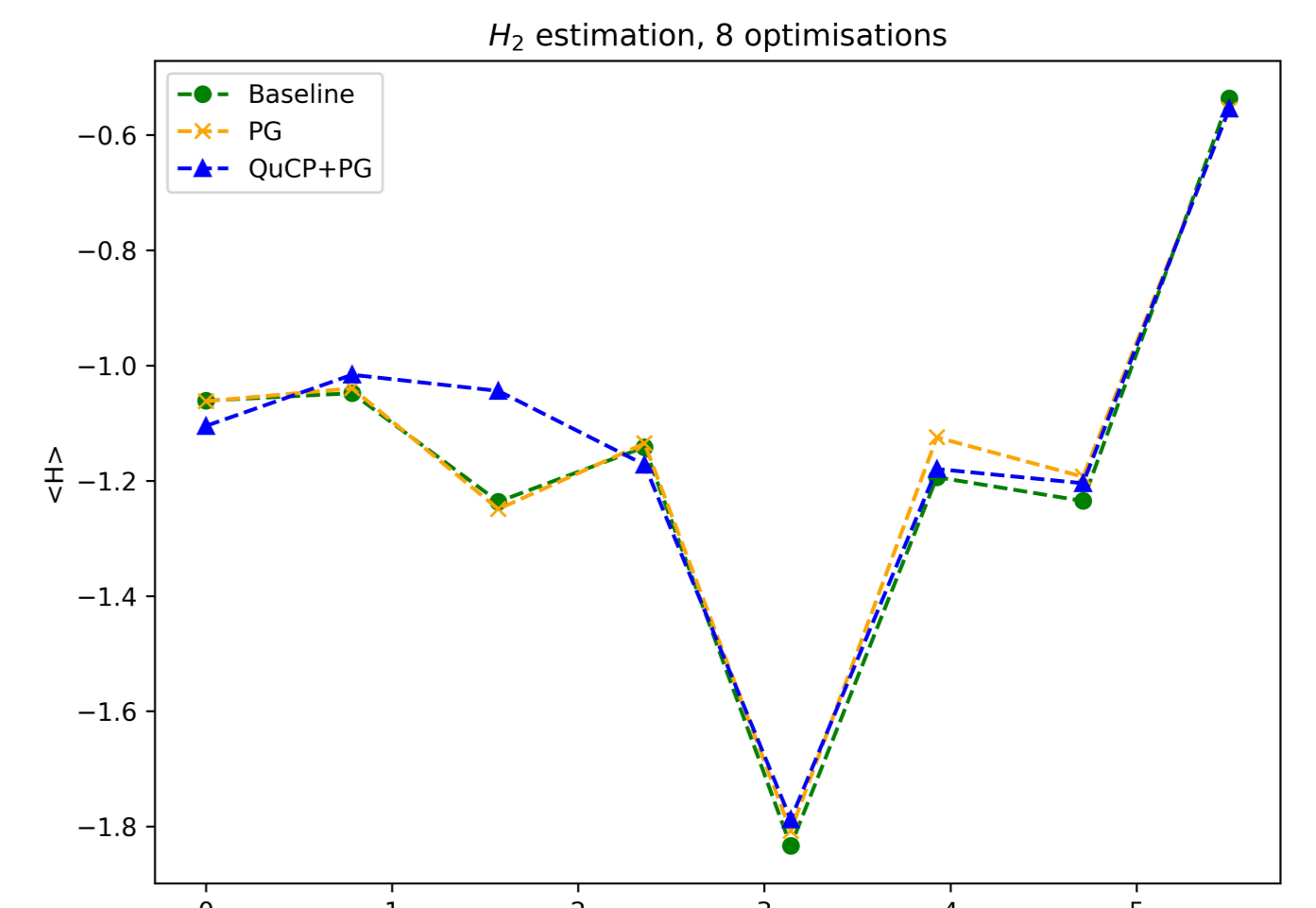
- Experiment setup
 - Execute different number of the same circuit on IBM Q 65 Manhattan.
 - Report the relation between hardware throughput and circuit fidelity.
- Results
 - # parallel circuit executions: one to six
 - Hardware throughput: 7.7% to 46.2%
 - Significant fidelity loss when hardware throughput is over **38%**.

Multiprogramming and VQE

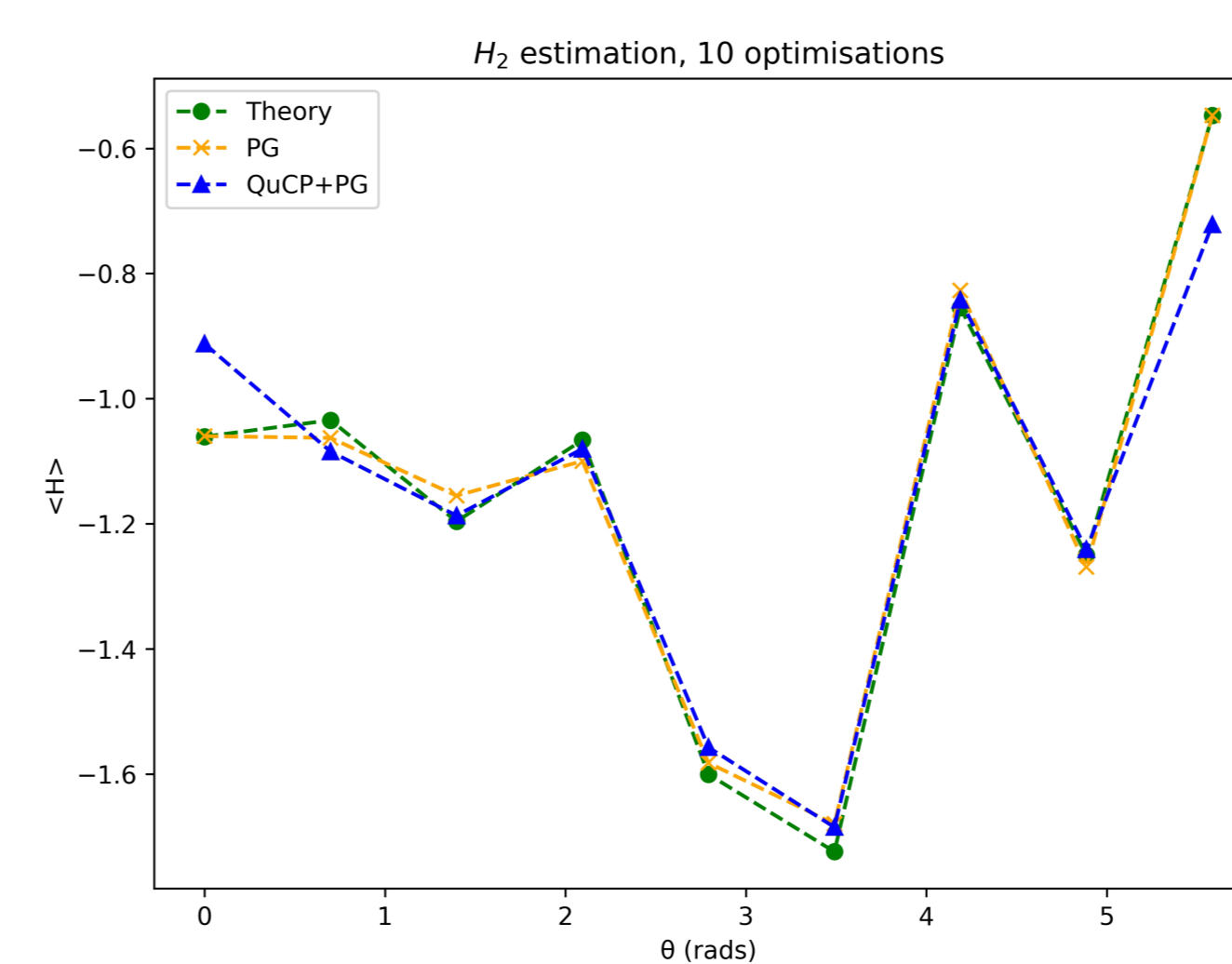
- VQE limitation
 - Split the computation into $O(N^4)$ sub-problems, introducing a large overhead of measurement circuits.
- Pauli grouping
 - Grouping commuting Pauli terms and measure them simultaneously.
- Idea
 - Apply multiprogramming to Pauli grouping

Experiment setup

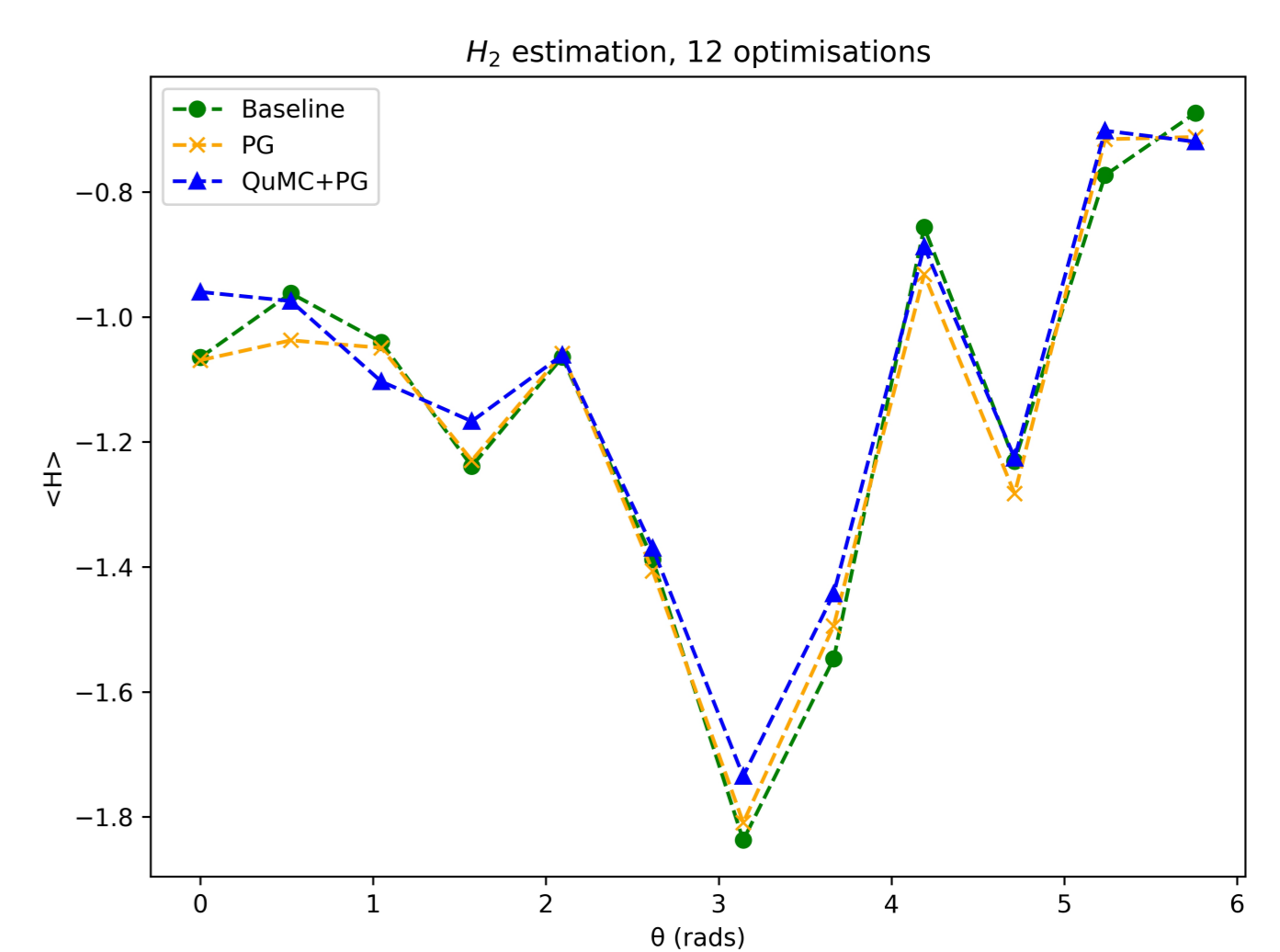
- Estimate ground state energy of H_2
 - Hamiltonian: $\{II, IZ, ZI, ZZ, XX\}$
- Heuristic ansatz state
- Two repetitions
- $RyRz$ on each qubit



(a) 8 optimizations with 16 measurements.



(b) 10 optimizations with 20 measurements.

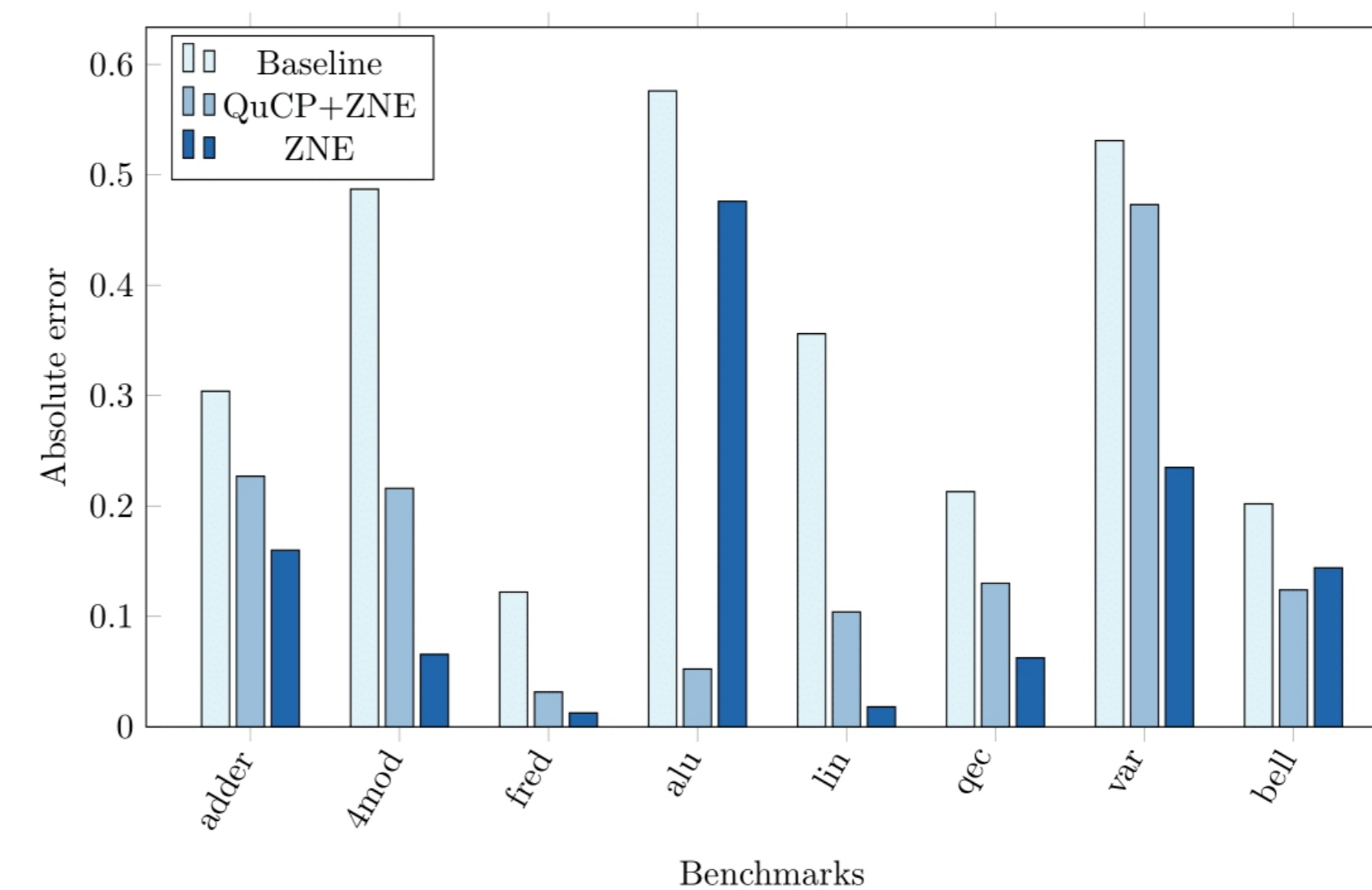


(c) 12 optimizations with 24 measurements.

- Results
 - Hardware throughput can be up to **73.8%** with an error rate of less than 10%.

Multiprogramming and ZNE

- Zero noise extrapolation (ZNE) error mitigation.
 - Noise-scaling
 - Extrapolation
 - Extra circuit overhead



- Results
 - The error rate is reduced by **2x** without any circuit overhead.

References

- [1] S.Niu et al. [arxiv.2112.00387](https://arxiv.org/abs/2112.00387), 2021.
- [2] S.Niu et al. [arxiv.2102.05321](https://arxiv.org/abs/2102.05321), 2021.
- [3] P.Gokhale et al. [QCE 2020](https://arxiv.org/abs/2005.00000).
- [4] Y.Li et al. [PRX 2017](https://arxiv.org/abs/1703.02901).

Acknowledgment

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